510-04
20218
N95- 14643

TABES 94

10th Annual

Technical and Business Exhibition and Symposium

May 10 - 11, 1994
Von Braun Civic Center
Huntsville, Alabama

A NASA/INDUSTRY/UNIVERSITY PARTNERSHIP FOR DEVELOPMENT OF DUAL-USE VIBRATION ISOLATION TECHNOLOGY

BY

MICHAEL L. TINKER
NASA/MARSHALL SPACE FLIGHT CENTER
PAYLOAD LOADS AND DYNAMICS BRANCH/ED26
HUNTSVILLE, AL 35812

TABES Paper
No. 94- 613

TABES Sponsored Annually by

Huntsville Association of Technical Societies

P.O. Box 1964
Huntsville, Alabama 35807
Telephone: 205-837-4287
Fax: 205-837-4275

A NASA/INDUSTRY/UNIVERSITY PARTNERSHIP FOR DEVELOPMENT OF DUAL-USE VIBRATION ISOLATION TECHNOLOGY

by

Michael L. Tinker
NASA/Marshall Space Flight Center
Payload Loads and Dynamics Branch/ED26
Huntsville, AL 35812

ABSTRACT

A partnership is described that was formed as a result of a NASA university grant for the study of wire rope vibration isolation systems. Vibration isolators of this type are currently used in the Space Shuttle Orbiter and engine test facility, and have potential application in the international Space Station and other space vehicles. Wire rope isolators were considered for use on the Hubble Space Telescope, leading to the NASA-funded university research into modeling of the isolators. The military has used wire rope technology extensively, and thus far military sales account for about 90 percent of sales in the industry. The desire of the wire rope industry to expand sales in commercial markets coupled with results of the prior NASA-funded study led to the formation of a partnership including NASA, the university involved in the research grant, and a small company that designs wire rope systems. Goals of the partnership include the development of improved mathematical models and a designer's handbook that would make the new modeling tools easy to use. Accomplishment of these objectives should not only expand commercial sales of wire rope systems, but could also provide NASA with solutions to various space vehicle vibration problems.

INTRODUCTION

Wire rope isolators constructed of helical cables (Fig. 1) have had extensive use in military systems, including the F-15 and F/B 111 aircraft, the Tomahawk cruise missile, Navy Aegis combat system shipboard electronics, and the M109 field artillery support vehicle. Other government applications include vibration isolation for Space Shuttle Orbiter fluid flow control devices and engine test facility water lines, as well as protection of electronics for National Oceanic and Atmospheric Administration (NOAA) weather research aircraft. NASA has an obvious interest in wire rope technology due its current and potential use in space vehicles. Helical cable isolators could find a number of future space applications, including Space Station components, optical observatory systems, and various launch vehicle payloads.

There are also a number of current commercial uses of wire rope technology, including Piper and Cessna aircraft noise and vibration, Norwegian watercraft propeller vibration, all-terrain and oil prospecting vehicles, and various protective containers. Potential commercial uses include isolation of industrial piping and machinery. However, about 90 percent of sales in this industry have been defense-related. Obviously, wire rope companies seek to expand sales in non-military markets, particularly with downsizing of defense budgets. Shock and Vibration Products, Inc., a small company specializing in design and application of helical cable isolators, believes that a key to opening commercial markets is improved isolator modeling and system performance analysis techniques.

Wire rope isolators work on the principle of sliding friction between contacting bodies to dissipate vibrational energy. As shown in Fig. 2, the fundamental element of a wire rope helical isolator is a length of cable consisting of several strands of wire wrapped around a metallic or fibrous core. The cable is wound in the shape of a helix and fastened with clamps to form an individual isolator (Fig. 1), and an isolation system is constructed by arranging a number of such isolators in the desired configuration. In Fig. 3 a simple system constructed from helical isolators is shown. As a system or component to which the isolators are attached vibrates, individual wires in the cables rub together, converting some of the kinetic energy into heat and thereby lowering the vibration amplitude.

Due to the construction of helical cable isolators, mathematical modeling is difficult. Design and application of this technology is currently done on an experimental basis by engineers with considerable experience in its use. There is a need for a well-developed analytical procedure for predicting the performance of the isolators in particular applications.

NASA RESEARCH GRANT FOR STUDY OF WIRE ROPE ISOLATORS

Helical cable isolators were investigated by NASA Marshall Space Flight Center and Sperry Corporation (Ref. 1) for possible use on the Hubble Space Telescope (HST) to isolate the pointing control system from the massive rotating reaction wheel assemblies. Figure 4 from Ref. 1 shows the HST reaction wheel assembly mounted on wire rope isolators. This investigation showed that helical cable isolators have complex characteristics and are difficult to model mathematically. In addition, the isolators were not ideal for the low level of vibration encountered in the microgravity environment. To address modeling concerns, a NASA research grant was awarded to Auburn University for the purpose of testing wire rope hardware and development of system models based on the test database.

As part of the work done at Auburn University, vibration tests of the simple system shown in Fig. 3 were performed. The relative motion of the center block (component being isolated) and the isolator frame was monitored to determine the dynamic characteristics of the system. Using the test data, mathematical models were developed to predict the isolator behavior, and good agreement was obtained between test and analysis. Additional information about this research is given in Refs. 2-4. The results of this work were received with considerable interest in the wire rope industry. Shock and Vibration Products, Inc. (SVP) made the statement that the work "...has been extremely helpful to SVP in the computer modeling of damping for shock response." However, as stated previously in this section, test results and analysis applied only to the isolator in Fig. 3. Additional work is needed to extend the results to general isolator configurations.

FORMATION OF A COOPERATIVE PARTNERSHIP FOR ADVANCING WIRE ROPE TECHNOLOGY

Based on the success obtained under the NASA research grant in modeling a particular wire rope isolator, a new partnership was formed including Shock and Vibration Products (SVP), Inc., the small wire rope company referred to in previous sections, Auburn University, and NASA Marshall Space Flight Center. SVP, Inc. has a desire to expand its sales in non-military markets in view of the declining military expenditures, and the interest of the military and NASA in wire rope technology has already been discussed. The partnership was formed to develop a proposal for the Technology Reinvestment Project (TRP), a federal program for defense technology conversion to the private sector.

The TRP has the mission to "...stimulate the transition to a growing, integrated, national industrial capability which provides the most advanced, affordable, military systems and the most competitive commercial products" (Ref. 5). Key words describing the TRP programs are "employment", "commercial" and "dual-use". Objectives of the programs are to use both federal and commercial funds (and other resources) to develop technologies having dual use (in both government and private industry), enhance U.S. competitiveness, expand employment, and assist displaced defense workers. In keeping with its objectives, the TRP invests in three technology activity areas: 1. Technology development to provide new products and processes, 2. Deployment of existing technology into military and commercial products and processes, and 3. Manufacturing Education and Training. The first two activities were of interest to the partnership described in this paper. Figure 5 (from Ref. 5) shows the relationship of these two activity areas and the stages of technology maturation.

Addressing the three technology activity areas described in the previous paragraph are eight TRP programs or funding sources. The programs of interest to the partnership and for which it was eligible to propose were the following: 1. Commercial-Military Integration Partnerships, having the purpose of developing and maturing dual-use technologies with obvious commercial viability and potential military applications, and 2. Defense Dual-Use Assistance Extension Program, designed to assist businesses economically dependent on defense expenditures to expand commercially. Figure 6 (Ref. 5) shows how the funding programs relate to the technology activity areas or stages of technology maturation.

The purpose of the partnership is to build on results obtained under the NASA research grant and develop more general analytical models that can be used for any helical cable isolation system to predict performance and aid design. In this manner, wire rope technology can be expanded in commercial markets, NASA would obtain new tools for solving launch vehicle and spacecraft vibration problems, and the military could more efficiently use the isolators it has relied upon for many years. Objectives of the partnership are to be achieved in a thorough program of testing and analysis of several wire rope geometries and loading conditions as described in the following section.

TECHNOLOGY DEVELOPMENT PLAN AND ROLES OF PARTNERS

For wire rope manufacturers to analytically design systems for a wide variety of applications, and thus move away from construction and laboratory testing of prototypes, analysis tools must be general in scope and applicable to all isolator geometries. Helical cable isolators vary in size from 1" x 3" up to 10" x 22", where the first dimension is the width of the helical loop and the second dimension is the length of the isolator (Fig. 1). Wire diameter varies from 1/16" to 1 1/4". Thus a number of different geometries must be tested and modeled in the development of general system analysis tools.

Proposed test activities include both shock and vibration tests of a number of isolators with varying cable diameter, loop size, and number of loops. Two to four identical isolators will be mounted underneath each corner of a mass simulator representing equipment to be protected (Fig. 7), and several mass simulators of various weights and sizes will be utilized to allow simulation of realistic applications. Analytically, it is planned to expand models developed in the previous NASA research grant to allow use of existing design data for all isolators now being manufactured. The models will be modified as necessary using the test data obtained in the proposed study. The final product will be an engineering tool in the form of a computer code and user guide for analysis of wire rope system performance. The cost of the study, to be equally shared among the partners and TRP, is approximately $250K.

The proposed responsibilities of the partners are generally that SVP, Inc. will provide wire rope hardware and assemble a database of current design data, Auburn University will perform most of the testing and analysis, and NASA Marshall Space Flight Center will assist in testing and analytical modeling. All three partners will cooperate in selection of test hardware and configurations, as well as review of measured data. Auburn University and NASA will cooperate in development and verification of models using measured test data, and SVP will provide general guidance throughout the technology development program due to their position in the industrial sector. The chart in Fig. 8 shows the partnership structure.

SUMMARY

A government/industry/university partnership has been described that has the purpose of advancing vibration isolation technology for dual use in commercial and government applications. A promising form of this technology, wire rope isolation, has been described in some detail. The technology plan for testing and analysis of a variety of wire rope devices, and for development of practical engineering analysis tools, was also discussed. Finally, the roles of the partners in the technology development plan were outlined.

REFERENCES

1. Davis, L.P., J.F. Wilson, R.E. Jewell, and J.J. Roden,"Hubble Space Telescope Reaction Wheel Assembly Vibration Isolation System", Damping 1986 Proceedings, AFWAL-TR-86-3059, Air Force Wright Aeronautical Labs, Wright-Patterson AFB, Ohio, pp. BA-1-BA-22.

2. Tinker, M.L., "Damping Phenomena in a Wire Rope Vibration Isolation System", Dissertation, Dept. of Aerospace Engineering, Auburn University, AL, 1989.

3. Tinker, M.L., "Modeling of Nonlinear Vibration Isolators Using the *Advanced Continuous Simulation Language* (ACSL)", Southeastern Simulation Conference 1993, Huntsville, AL, Oct. 1993.

4. Cutchins, M.A., J.E. Cochran, K. Kumar, M.L. Tinker, and D.D. Newton, "Investigation of Damping Phenomena in Wire Rope Isolators and Their Potential for Use in Space Applications", Final Report, NASA Research Grant NAG8-647, Auburn University, AL, Dec. 1988.

5. Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance, Advanced Research Projects Agency, Arlington, VA, Mar. 1993.

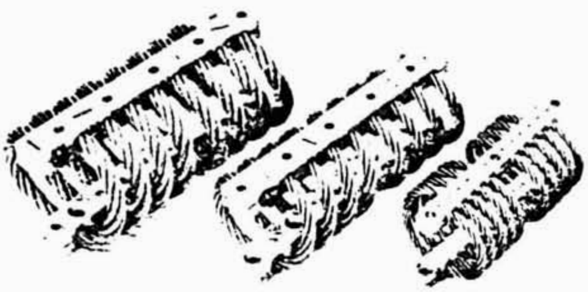

Figure 1. Helical Wire Rope Vibration Isolators.

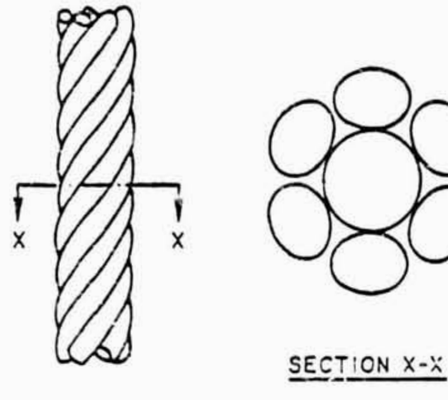

Figure 2. Basic Element of Wire Rope Systems.

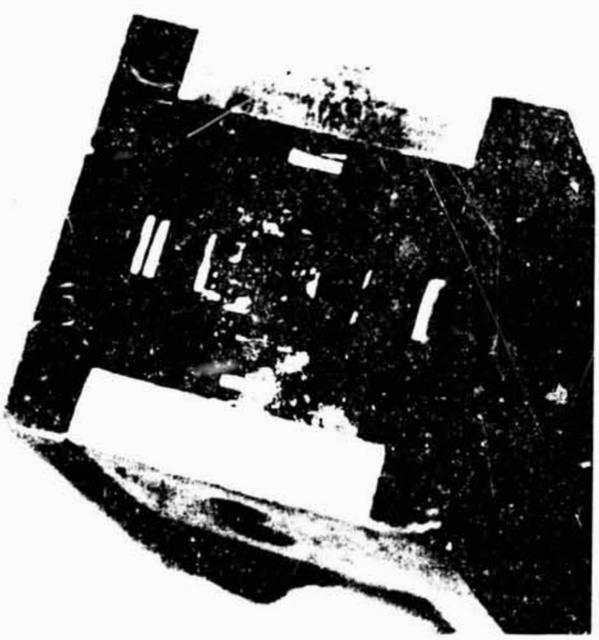

Figure 3. Simple System Constructed with Four Helical Isolators.

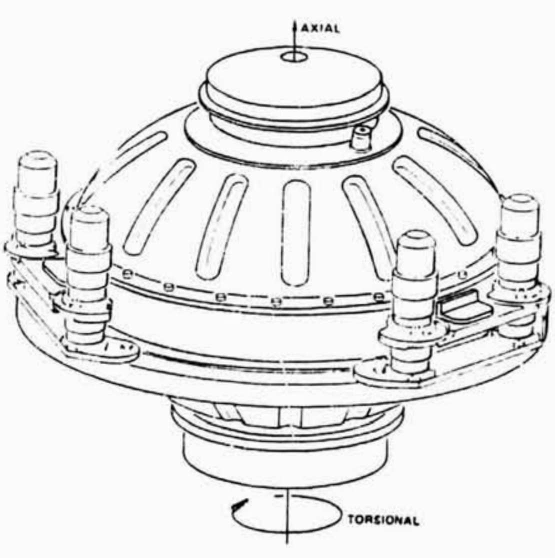

Figure 4. Hubble Space Telescope Reaction Wheel Mounted on Wire Rope Isolators.

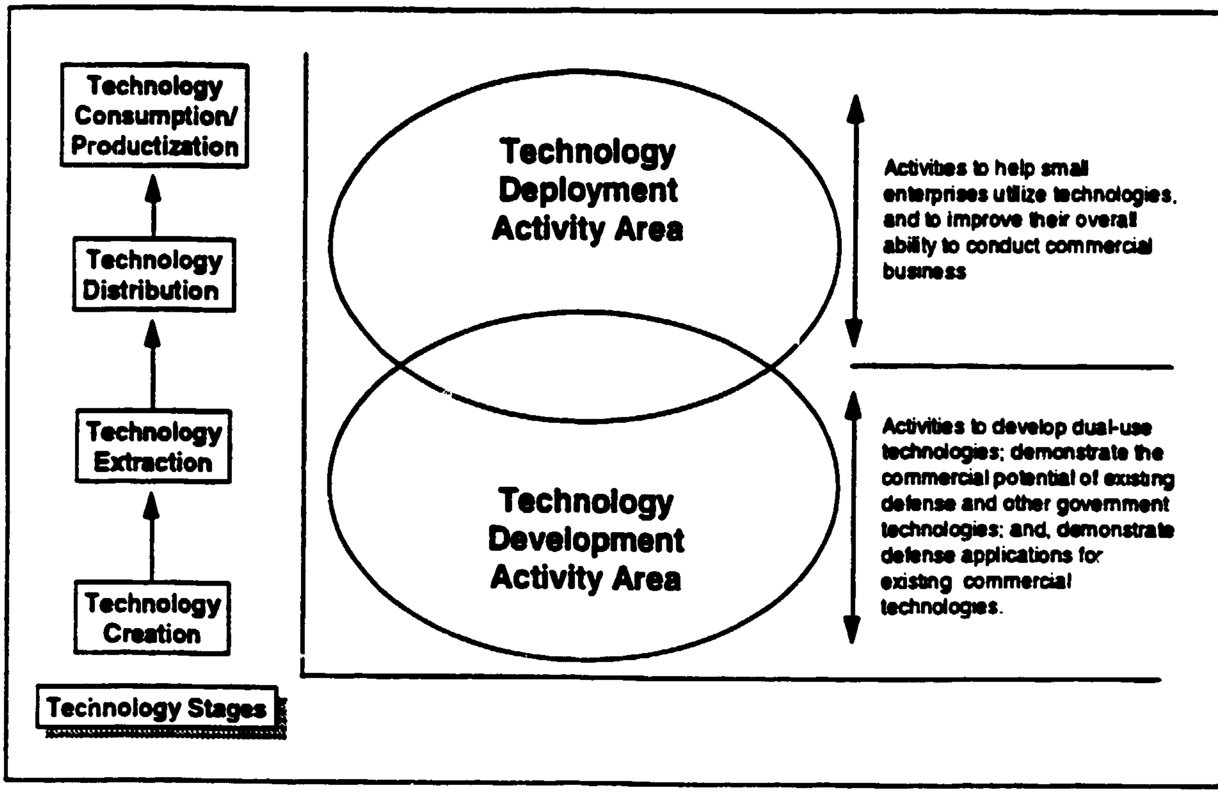

Figure 5. Technology Reinvestment Project (TRP) Activity Areas Related to Technology Stages.

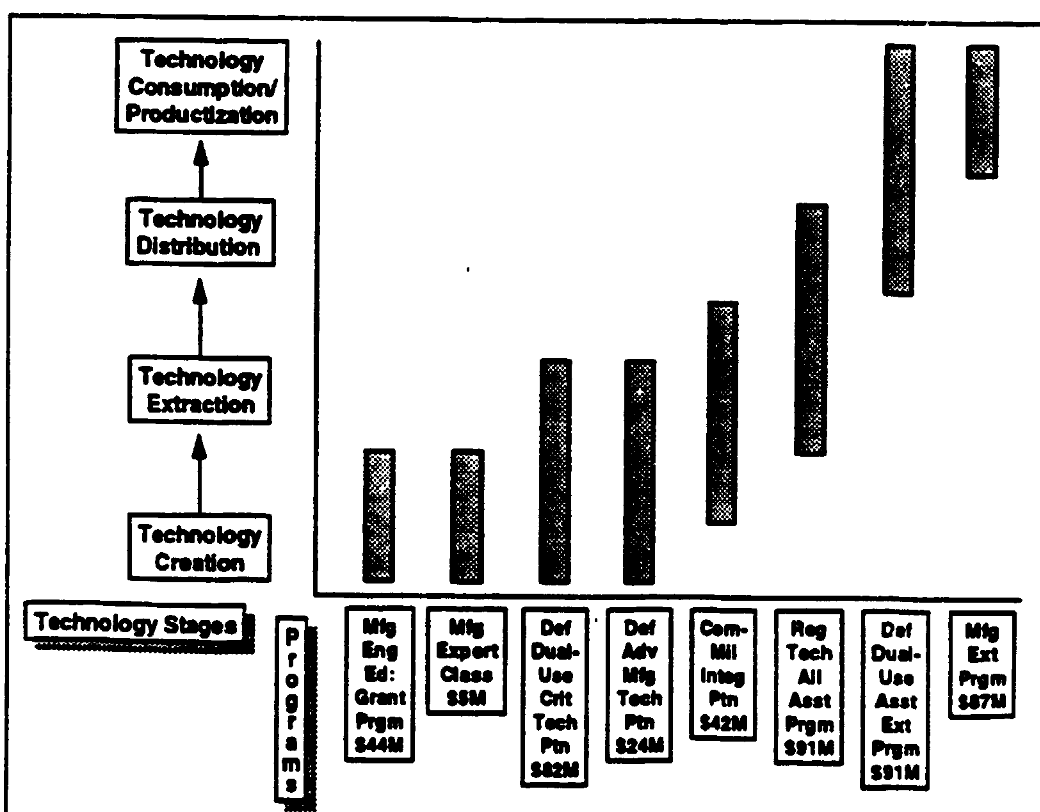

Figure 6. TRP Funding Programs Corresponding to Stages of Technology Maturation.

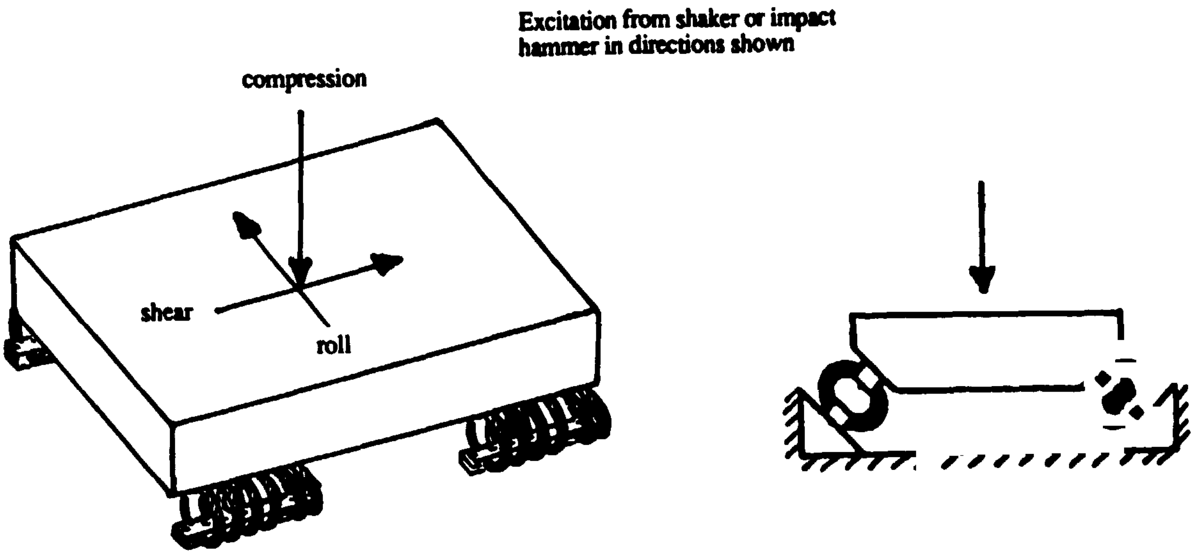

Figure 7. Two Proposed Wire Rope Test Configurations.

PRODUCT DEVELOPMENT ACTIVITY	PARTNER CONTRIBUTIONS					
	SVP, Inc.		Auburn University			NASA-MSFC
	Manpower	Hardware	Manpower	Facilities and Equipment	Computing Resources	Manpower/Co-Prin. Investigator
Design/build test articles	√	√	√	√	√	√
Plan tests/develop matrix	√		√			√
Perform vibration tests			√	√	√	
Perform shock tests			√	√	√	
Review test data	√		√			√
Reduce test data/report			√			
Scale test data/ generalize to other geometries	√		√			√
Assess available models			√		√	√
Prepare wire rope database	√					
Develop SDOF models	√		√		√	√
Correlate SDOF models to shock and vibration tests	√		√		√	√
Study MDOF models/modal math./building block math.			√		√	√
Develop engineering methodology tools	√		√		√	√

Figure 8. Structure of NASA/Industry/University Cooperative Partnership.